IS 3104-2 (1982): Density Hydrometers, Part II: Methods of Test and Use [CHD 10: Glassware]

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Indian Standard

SPECIFICATION FOR DENSITY HYDROMETERS

PART II METHODS OF TEST AND USE

(*First Revision*)

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Indian Standard

SPECIFICATION FOR DENSITY HYDROMETERS

PART II METHODS OF TEST AND USE

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Indian Standard

SPECIFICATION FOR DENSITY HYDROMETERS

PART II METHODS OF TEST AND USE

(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part II) (First Revision) was adopted by the Indian Standards Institution on 30 January 1982, after the draft finalized by the Laboratoryware and Related Apparatus Sectional Committee had been approved by the Chemical Division Council.

0.2 This standard was first published in 1965. The first revision of this standard aligns with the revised ISO : 649-1968 'Laboratory glassware — Density hydrometers for general purposes', issued by the International Organization for Standardization (ISO).

0.3 In this revision the standard has been prepared in two parts; Part I covers requirements of hydrometers and Part II covers methods of test and use of these hydrometers.

0.4 Part II prescribes the methods of test and use of hydrometers to obtain results with high precision introducing the correction factors due to hydrometers scale error; meniscus height of the liquid; and difference between surface tension and/or temperature of the liquid and that for which the hydrometer is graduated.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part II) specifies the methods of test and use of density hydrometers for general purposes.

*Rules for rounding off numerical values (*revised*).

2. METHODS OF DETERMINATION OF DENSITY BY MEANS OF HYDROMETERS

2.1 General — To obtain the highest precision when using a particular hydrometer, the following general procedures should be adhered to.

2.1.1 Read the hydrometer in the liquid at a known temperature.

2.1.2 Apply corrections (when significant) to the observed reading for:

a) the meniscus height (if the test liquid is opaque) (*see* **2.6.1**);

b) the scale error of the hydrometer at the observed reading (*see* **2.6.2**);

c) the difference between the temperature of the liquid and the standard temperature of the hydrometer (*see* **2.6.3**); and

d) the difference between the surface tension of the liquid and that for which the hydrometer is graduated (*see* **2.6.4**).

2.2 Apparatus

2.2.1 *Hydrometer* — Select a hydrometer appropriate to the surface tension of the liquid to be examined. Table 1 of IS : 9621-1980* gives a guide to the range of liquids suitable for the appropriate hydrometer category. Surface tensions of other liquids may be obtained from appropriate tables of physical properties of substances, for example, 'International Critical Tables'.

2.2.2 *Hydrometer Vessel* — Select a hydrometer vessel as described in 5.

2.2.3 *Thermometer* — For high precision work, select a total immersion thermometer graduated in 0.1°C, with a certificate of scale correction. A thermometer complying with IS : 4825-1962† is suitable.

2.3 Preliminaries

2.3.1 Clean all apparatus before use.

2.3.2 Allow the liquid to attain thermal equilibrium with its surroundings and pour it into the hydrometer vessel, allowing a small quantity to overflow if an overflow vessel is used. Avoid the formation of air bubbles in the liquid by pouring down the side of the vessel. Stir the liquid vertically with a loop stirrer, again avoiding the formation of bubbles. Record the temperature of the liquid to the nearest 0.2°C.

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*Principles of construction and adjustment of glass hydrometers.

†Laboratory and reference thermometers (*first revision*).

2.3.3 Insert the hydrometer carefully into the liquid, holding it by the top of its stem. Release the hydrometer when it is approximately in its position of equilibrium and, if an overflow vessel is used, add a further amount of sample to the vessel by way of the filling tube until a volume approximately equal to 15 percent of the nominal capacity has overflowed. A little experience soon enables the user to appreciate when the hydrometer is approaching equilibrium and to release it in such a position that the hydrometer rises or falls by only small amount when released. This is important with viscous liquids, for otherwise excess liquid will adhere to the stem and the hydrometer will thereby be weighted down.

2.3.4 When the hydrometer is steady, press the top of the stem downwards a few millimetres beyond the position of equilibrium or, if the liquid is viscous, only one scale division, gripping the stem very lightly with a finger and thumb. Withdraw the hand and observe the meniscus as the hydrometer oscillates to equilibrium. If the stem and liquid surface are clean, the meniscus shape will remain unchanged as the hydrometer rises and falls. If the meniscus shape changes, for example, if it wrinkles or is distorted by the motion of the hydrometer. lack of cleanliness is indicated and the hydrometer and vessel shall be cleaned and the test rep???ed with a fresh sample. This precaution becomes increasingly important with increasing surface tension of the liquid.

2.4 Reading the Hydrometer — When the hydrometer, which must not be touching; the side of the vessel, has settled down to its equilibrium position (in the case of viscous liquids this may take some time), record the reading as follows.

2.4.1 *Transparent Liquids* — Record the scale reading corresponding to the plane of intersection of the horizontal liquid surface and the stem. When taking the reading, view the scale through the liquid, adjusting the line of sight so that it is in the plane of the liquid surface.

2.4.2 *Opaque Liquids* — Record the scale reading where the meniscus merges into the stem of the hydrometer.

2.5 Reading of Temperature — Immediately after taking the reading, measure the temperature of the liquid to the nearest 0.2°C. The mean of this temperature and the initial temperature referred to in **2.3.2** shall be used in the calculation of corrections (*see* **2.6**).

NOTE — This is particularly important in the case of liquids having high values of coefficient of cubical thermal expansion.

The difference between two temperatures shall not exceed 1°C and if a larger difference is found, lack of thermal equilibrium is indicated, and the procedure shall be repeated from **2.3.2.**

2.6 Application of the Corrections

2.6.1 *Meniscus Height* — In cases where a hydrometer adjusted for readings taken at the level of the horizontal liquid surface has been read in an opaque liquid (that is at the line where the liquid merges into the stem of the hydrometer), it is necessary to correct the reading for the meniscus height by adding the appropriate value from Table 3 or Table 4.

2.6.2 *Instrument Error* — By instrument error is meant the difference between the reading of the hydrometer and the reading of a similar but ideal hydrometer used under precisely the same conditions. If known, the corrections for instrument error may be applied with equal validity under all conditions of use. It is, however, additional to other corrections, for example, those for temperature and surface tension, which vary according to conditions of use. For many purposes it is sufficient to know that the instrument error does not exceed the maximum error permitted under the Specification. Where great eraccuracy is required the instrument error should be known and allowed for.

In this case the hydrometer shall be tested. The linear dimension shall be checked with suitable graduated metal scales and outside micrometer calipers to verify that they comply with the requirements of IS : 3104 (Part I)-1982*.

a) The scale of hydrometer of the *L*20, *L*50 and *L*50*SP* series shall be tested on at least five points within the nominal limits, which shall include at least 80 percent of the graduated interval of the scale.

   Neither of the extreme points shall be further from the nearest end of the graduated scale than a distance equal to 15 percent of the graduated scale.

   No two adjacent points shall be further apart than a distance equal to 25 percent of the graduated scale; and

b) The scale of hydrometers of all other series shall be tested in a similar way following the same order as in (a) at three points, which shall include at least 60 percent of the graduated interval of the scale.

   Neither of the extreme points shall be further from the nearest end of the graduated scale than a distance equal to 25 percent of the graduated scale.

   No two adjacent points shall be further apart than a distance of 50 percent of the graduated scale, provided that the accuracy of the corrections is specified.

*Specification for density hydrometer : Part I Requirements (*first revision*).

When the scale is tested, it shall be verified that the scale has not shifted since manufacture, and the hydrometer shall be examined subsequently, from time to time, to ascertain that there has been no displacement of the scale.

2.6.3 *Temperature Correction* — If the hydrometer reading is taken at a temperature other than the reference temperature for the hydrometer, then the reading will be in error due to the change in volume of the hydrometer between the two temperatures.

Appropriate corrections making allowance for this temperature effect are given in Table 1. When positive in sign the temperature correction given is to be added to, and when negative, subtracted from the hydrometer reading at the time temperature in question. The tables have been computed using a nominal coefficient of cubical thermal expansion of the glass of the hydrometer having a value of $25 \times 10^{-6} (°C)^{-1}$.

TABLE 1 CORRECTION FOR TEMPERATURE APPLICABLE TO HYDROMETERS ADJUSTED FOR A REFERENCE TEMPERATURE OF 20°C OR 15°C

(*Clause* 2.6.3)

REFERENCE TEMPERATURE		READING							
15°C	20°C	kg/m3 600	800	1 000	1 200	1 400	1 600	1 800	2 000
Temperature of liquid °C		g/ml 0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	0	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9	+1.0
0	5	+0.2	+0 3	+0.4	+0.5	+0.5	+0.6	+0.7	+0.8
5	10	+0.2	+0.2	+0.3	+0.3	+0.4	+0.4	+0.5	+0.5
10	15	+0.1	+0.1	+0.1	+0.2	+0.2	+0.2	+0.2	+0.3
15	20	0	0	0	0	0	0	0	0
20	25	–0.1	–0.1	–0.1	–0.2	–0.2	–0.2	–0.2	–0.3
25	30	–0.2	–0.2	–0.3	–0.3	–0.4	–0.4	–0.5	–0.5
30	35	–0.2	–0.3	–0.4	–0.5	–0.5	–0.6	–0.7	–0.8
35	40	–0.3	–0.4	–0.5	–0.6	–0.7	–0.8	–0.9	–1.0
40	45	–0.4	–0.5	–0.6	–0.8	–0.9	–1.0	–1.1	–1.3

NOTE — These corrections when applied to the hydrometer reading at *t*°C give the density of the liquid in kg/m^3 or g/ml at *t*°C. They are based on the relation-chip:

$$C = 0.000\ 025\ R\ (\ t_2 - t\ )$$

where

C = correction,
R = reading at the level of the horizontal liquid surface,
t_2 = reference temperature, and
t = temperature of the liquid being meaiured.

2.6.4 *Surface Tension Correction* — Attention has already been drawn to the fact that the reading of a hydrometer depends to some extent on the surface tension of the liquid in which it is used. In general it is possible, by choosing a hydrometer graduated for the most appropriate of the surface tension categories [*see* IS : 3104 (Part 1)-1982*] and having a suitable open scale, to avoid any necessity for surface tension corrections. Table 2 gives an indication of possible errors in the form of corrections which may be applied on account of difference between the surface tension of the liquid and the surface tension for which the hydrometer is adjusted. They relate to hydrometers of average dimensions permitted under this specification.

It is important to note that the density obtained by applying this correction is that of the liquid at the temperature of observation. If the density is required at some other temperature an allowance must be made for the expansion or contraction of the liquid with change of temperature (*see* **2.6.3**).

3. MENISCUS CORRECTIONS

3.1 Table 3 gives the approximate amounts to be added to readings taken where the top of the meniscus appears to meet the stem, in order to obtain the corresponding indications at the level of the horizontal liquid surface. They have been calculated for hydrometers having the mean dimensions permitted by the specification and are based on an equation due to Langberg which, rearranged, is equivalent to :

$$\rho - \rho_0 = \frac{1\,000\,\Delta a\,\sigma}{g_n \Delta l D \rho_0} \sqrt{1 + \frac{2 g_n D^2 \rho_0}{1\,000 \sigma}} - 1$$

where

ρ = density reading at the level of the horizontal liquid surface, in kilograms per cubic metre;

ρ_0 = density reading at the top of the meniscus, in kilograms per cubic metre;

Δa = scale interval, in kilograms per cubic metre;

σ = surface tension, in millinewtons per metre;

g_n = acceleration due to gravity, in metres per second squared, taken as the standard acceleration of 9791 387 m/s^2;

D = stem diameter, in millimetres; and

Δl = scale spacing, in millimetres.

NOTE — International value of acceleration due to gravity, ' g ' is 9.806 65 m/s^2.

*Specification for density hydrometers : Part I Requirements (*first revision*).

TABLE 2 SURFACE TENSION CORRECTIONS

Unit : Kg/m^3 or 10^{-3} g/ml

(*Clause* 2.6.4)

SURFACE TENSION OF LIQUID MINUS THAT FOR WHICH THE HYDROMETER IS ADJUSTED mN/m	SERIES *L*20 HYDROMETER READING				SERIES *L*50 AND *L50SP* HYDROMETER READING				SERIES *M*50 AND *M50SP* HYDROMETER READING				SERIES *M*100 HYDROMETER READING				SERIES *S*50 AND *S*50*SP* HYDROMETER READING			
	kg/m3 600 g/ml 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
–40	—	–0.54	–0.45	–0.39	—	–1.2	–0.9	–0.8	–	–1.9	–1.5	–1.4	—	–3.0	–3.0	–2.0	–3.0	–2.5	–2.0	–2.0
–30	—	–0.41	–0.34	–0.30	—	–0.9	–0.7	–0.6	—	–1.4	–1.1	–1.0	—	–2.0	–2.0	–2.0	–2.5	–2.0	–1.5	–1.5
–20	—	–0.27	–0.22	–0.20	—	–0.6	–0.5	–0.4	—	–0.9	–0.8	–0.7	—	–2.0	–1.0	–1.0	–1.5	–1.5	–1.0	–1.0
–10	–0.18	–0.14	–0.11	–0.10	–0.3	–0.3	–0.2	–0.2	–0.6	–0.5	–0.4	–0.3	–1.0	–10	–1.0	–1.0	–1.0	–0.5	–0.5	–0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+10	+0.18	+0.14	+0.11	+0.10	+0.3	+0.3	+0.2	+0.2	+0.6	+0.5	+0.4	+0.3	+1.0	+1.0	+1.0	+1.0	+1.0	+0.5	+0.5	+0.5
+20	—	+0.27	+0.22	+0.20	—	+0.6	+0.5	+0.4	—	+0.9	+0.8	+0.7	—	+2.0	+1.0	+1.0	+1.5	+1.5	+1.0	+1.0
+30	—	+0.41	+0.34	+0.30	—	+0.9	+0.7	+0.6	—	+1.4	+1.1	+1.0	—	+2.0	+2.0	+2.0	+2.5	+2.0	+1.5	+1.5
+40	—	+0.54	+0.45	+0.39	—	+1.2	+0.9	+0.8	—	+1.9	+1.5	+1.4	—	+3.0	+3.0	+2.0	+3.0	+2.5	+2.0	+2.0

NOTE — For hydrometers not of average dimension, the surface tension allowances may differ from the above amounts by up to approximately ± 10 percent.

TABLE 2 SURFACE TENSION CORRECTIONS

Unit : Kg/m^3 or 10^{-3} g/ml

(*Clause* 2.6.4)

SURFACE TENSION OF LIQUID MINUS THAT FOR WHICH THE HYDROMETER IS ADJUSTED mN/m	SERIES *L*20 HYDROMETER READING				SERIES *L*50 AND *L*50*SP* HYDROMETER READING				SERIES *M*50 AND *M*50*SP* HYDROMETER READING				SERIES *M*100 HYDROMETER READING				SERIES *S*50 AND *S*50*SP* HYDROMETER READING			
	kg/m^3 600 g/ml 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0	600 0.6	1 000 1.0	1 500 1.5	2 000 2.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
–40	—	–0.54	–0.45	–0.39	—	–1.2	–0.9	–0.8	—	–1.9	–1.5	–1.4	—	–3.0	–3.0	–2.0	–3.0	–2.5	–2.0	–2.0
–30	—	–0.41	–0.34	–0.30	—	–0.9	–0.7	–0.6	—	–1.4	–1.1	–1.0	—	–2.0	–2.0	–2.0	–2.5	–2.0	–1.5	–1.5
–20	—	–0.27	–0.22	–0.20	—	–0.6	–0.5	–0.4	—	–0.9	–0.8	–0.7	—	–2.0	–1.0	–1.0	–1.5	–1.5	–1.0	–1.0
–10	–0.18	–0.14	–0.11	–0.10	–0.3	–0.3	–0.2	–0.2	–0.6	–0.5	–0.4	–0.3	–1.0	–1.0	–1.0	–1.0	–1.0	–0.5	–0.5	–0.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
+10	+0.18	+0.14	+0.11	+0.10	+0.3	+0.3	+0.2	+0.2	+0.6	+0.5	+0.4	+0.3	+1.0	+1.0	+1.0	+1.0	+1.0	+0.5	+0.5	+0.5
+20	—	+0.27	+0.22	+0.20	—	+0.6	+0.5	+0.4	—	+0.9	+0.8	+0.7	—	+2.0	+1.0	+1.0	+1.5	+1.5	+1.0	+1.0
+30	—	+0.41	+0.34	+0.30	—	+0.9	+0.7	+0.6	—	+1–4	+1–1	+1–0	—	+2.0	+2.0	+2.0	+2.5	+2.0	+1.5	+1.5
+40	—	+0.54	+0.45	+0.39	—	+1.2	+0.9	+0.8	—	+1.9	+1.5	+1.4	—	+3.0	+3.0	+2.0	+3.0	+2.5	+2.0	+2.0

NOTE — For hydrometers not of average dimension, the surface tension allowances may differ from the above amounts by up to approximately ± 10 percent.

TABLE 3 AVERAGE MENISCUS CORRECTIONS EXPRESSED IN UNITS OF DENSITY

Unit : kg/m^3 or $10^{-3}g/ml$

(*Clause* 3.1)

Series of hydrometers → Smallest scale interval → Density of liquid kg/m³	g/ml	Surface tension mN/m	*L20* 0.2	*L50* and *L50SP* 0.5	*M50* and *M50SP* 1	*M100* 2	*S50* 2	*S50SP* 1
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
600	0.600	15	0.32	0.7	1.2	2.0	1.6	1.6
800	0.800	25	0.35	0.7	1.4	2.4	1.6	1.8
1 000	1.000	35	0.36	0.7	1.4	2.4	1.6	1.8
		55	0.44	0.9	1.6	2.8	2.0	—
		75	0.48	1.0	1.8	3.2	3.2	—
1 500	1.500	35	0.28	0.6	1.2	2.0	1.6	1.4
		55	0.36	0.7	1.4	2.4	1.6	—
		75	0.40	0.8	1.6	2.4	2.4	—
2 000	2.000	55	0.32	0.6	1.2	2.0	1.6	—
		75	0.36	0.7	1.4	2.4	2.4	—

3.2 Those requiring to know the corrections for meniscus height more closely than can be obtained from the above table of average values may derive them, having regard to the diameter of the stem of the particular hydrometer concerned, from Table 4 which is also computed from Langberg's equation.

4. TABLE FOR USE IN CALCULATION QUANTITIES OF LIQUID IN BULK

4.1 At a given temperature t °C, the volume v_t in cubic metres or millilitres of a quantity of liquid can be obtained by dividing its apparent mass in air, W kilograms or grams, by the apparent mass in air of the liquid per cubic metre or per millilitre respectively. Alternatively, the total apparent mass in air of the liquid at t °C, W kilograms or grams, can be found by multiplying together the total volume of the liquid v_t cubic metres or millilitres, and the apparent mass in air at t °C, in kilograms per cubic metre or grams per millilitre respectively. In both instances, the

apparent mass in air per unit volume at t °C is required and Table 5 enables these quantities to be obtained in a simple way from the density (kg/m^3 or g/ml) at t °C. The correction in the third or fourth column, whichever is appropriate, is to be applied to the corresponding value in the first or second column.

NOTE — In the petroleum industry special calculation procedures based on the reference temperature 15°C are used, and the necessary tables are included in petroleum measurement tables.

TABLE 4 AVERAGE MENISCUS CORRECTION EXPRESSED IN UNITS OF LENGTH

Unit : 1 mm

(*Clause* 3.2)

DENSITY OF LIQUID		SURFACE TENSION	STEM DIAMETER mm			
kg/m^3	g/ml	mN/m	4	5	6	7
(1)	(2)	(3)	(4)	(5)	(6)	(7)
600	0.6	15	1.7	1.8	1.9	1.9
700	0.7	20	1.8	1.9	2.0	2.0
800	0.8	25	1.9	2.0	2 0	2.1
900	0.9	30	1.9	2.0	2 1	2.2
1 000	1.0	35	1.9	2.1	2.1	2.2
		55	2.2	2.4	2.5	2.6
1 300	1.3	35	1.8	1.9	1.9	2.0
		35	2.1	2.2	2.3	2.4
1 500	1.5	55	2.0	2.1	2.2	2.3
2 000	2.0	55	1.8	1.9	1.9	2.0

4.2 When the temperature of observation of the density is not the same as the temperature at which the volume of the liquid is required or measured, the expansion or contraction of the liquid between the two temperatures must be taken into account. The volume v_t' at t' °C can he obtained from v_t (found as indicated above) by using the relationship :

$$V'_t = V_t[1 + \gamma (t' - t)]$$

where γ is the mean coefficient of cubical thermal expansion of the liquid over the temperature range t to t'°C.

TABLE 5 CONVERSION OF DENSITY (kg/m^3 or g/ml.) TO APPARENT MASS (IN AIR) IN kg or g OF THE LIQUID OCCUPYING 1 m^3 or 1 ml AT A GIVEN TEMPERATURE, t °C

(*Clause* 4.1)

DENSITY AT t °C		CORRECTION TO GIVE APPARENT MASS IN AIR OF LIQUID	
		Occupying 1 m^3 at t °C	Occupying 1 ml at t °C
kg/m^3	g/ml	kg/m^3	g/ml
(1)	(2)	(3)	(4)
600 to 1 100	0.6 to 1.1	–1.1	–0.001 1
1 200 to 1 700	1.2 to 1.7	–1.0	–0.001 0
1 800 to 2 000	1.8 to 2 0	–0.9	–0.000 9

NOTE 1 — These figures are based on 1.2 kg/m^3 and 8 000 kg/m^3 the densities of the atmosphere and of the weights used.

NOTE 2 — The equivalence of the cubic decimetre and the litre (1964 CGPM definition) is assumed.

4.2.1 Similarly, when the total apparent mass W is required, the density being known at t °C and the total volume v_t' at t' °C. then the volume v_t at t °C can be found from v_t' by dividing it by $[1 + v' (t' - t)]$.

5. VESSELS FOR HYDROMETER OBSERVATIONS

5.1 For all liquids, a cylindrical hydrometer vessel is normally suitable, but for results of tiie highest precision of liquids of high surface tension an overflow vessel should be used so that the surface film can be removed.

5.2 Cylindrical Vessels — The cylinder should stand firmly on its base and should be free from local irregularides producing distortion. In Table 6, the capacities of suitable graduated cylinders are given. Graduated, or preferably ungraduated cylinders of these sizes will doubtless be available to hydrometer users. Larger cylinders are of course at least equally satisfactory when sufficient liquid is available. Shorter cylinders can be used when the length of the hydrometer is not near the maximum permitted, or when the scale reading is not near the top of the stem. The diameter of the cylinder employed should be several millimetres greater than the hydrometer bulb diameter.

5.3 Overflow Vessels — Overflow vessels suitable for hydrometers are shown in Fig. 1. The internal diameter of the vessel and the distance of

the overflow level from the top and the bottom of the vessel should be kept within the limiting values shown, but small variations in the remaining dimensions are unimponant. The vessels illustrated can be made easily from glass tubing; they require a stand to hold them. Type A is suitable for series *L*20 and *L*50. Type B for series *M*100 and Type C for series *S*50 hydrometers.

TABLE 6 CYLINDERS SUITABLE FOR OBERVATION ON HYDROMETERS

(*Clause* 5.2)

HYDROMETER SERISE	MAXIMUM BULD DIAMETER mm	MAXIMUM LENGTH OF HYDRO-METRE TO TOP GRADUATION MARK mm	NOMINAL CAPACITY OF CYLINDER ml
(1)	(2)	(3)	(4)
*L*20	40	320	1 000
*L*50 and *L*50*SP*	27	320	1 000
*M*50 and *M*50 *SP*	24	255	500
*M*100	20	235	250
*S*50 and *S*50*SP*	20	175	250

6. DENSITY OF AIR-FREE DISTILLED WATER

6.1 Although the demity of water at 4°C is not a fundamental quantity in the International System of Units, water is still used as a standard substance for precise volume and density measurements. The tables for the density of water used up to now, based on the International Practical Temperature Scale of 1948 and on the litre in the definition valid up to 1964, have been recalculated by Wagenbreth and Blanke using the unit of volume of the International System of Units and the International Practical Scale of Temperature (1968) (IPTS-68). These new values are fives in Table 7. In addition, the differences between the densities of air-free and air-saturated water and the rate of density change with temperature are given.

7. DIFFERENCES BETWEEN READINGS ON HYDROMETERS ADJUSTED ON VARIOUS BASES OF SCALE

7.1 The data in Table 8 are of use when adjusting or testing a hydrometer against a reference instrument not adjusted in the appropriate units (for example, pyknometers (*see* IS : 5717-1970*)].

*Specification for pyknometers

TABLE 7 DENSITY OF WATER IN kg/m^3 AGAINST °C OF THE INTERNATIONAL PRACTICAL SCALE OF TEMPERATURE (1968)

(*Clause* 6.1)

t68 °C (1)	0.0 (2)	0.1 (3)	0.2 (4)	0.3 (5)	0.4 (6)	0.5 (7)	0.6 (8)	0.7 (9)	0.8 (10)	0.9 (11)	kg/m^3 0.1°C (12)	Δp AIR-SATURATED MINUS AIR-FREE (13)
0	999.839 6	999.846 3	999.852 8	999.859 1	999.865 3	999.871 3	999.877 1	999.882 7	999.888 2	999.893 4	0.005 9	−0.002 6
1	999.898 5	999.903 5	999.908 2	999.912 8	999.917 2	999.921 4	999.925 4	999.929 3	999.933 0	999.936 5	0.0041	−0.002 7
2	999.939 9	999.943 1	999 946 1	999.948 9	999.951 6	999.954 1	999.956 5	999.958 7	999.960 7	999.962 5	0.002 4	−0.002 8
3	999.964 2	999.965 7	999.967 0	999.968 2	999.969 2	999.970 1	999.970 8	999.971 3	999.971 7	999.971 9	0.000 8	−0.003 0
4	999.972 0	999.971 8	999.971 6	999.971 1	999.970 5	999.969 8	999.968 9	999.967 8	999.966 6	999.965 2	−0.0008	−0.003 1
5	999.963 7	999.962 0	999.960 2	999.958 2	999.956 0	999.953 7	999.951 3	999.948 7	999.945 9	999.943 0	−0.002 4	−0.003 3
6	999.939 9	999.936 7	999.933 4	999.929 9	999.926 2	999.922 4	999.918 4	999.914 3	999.910 1	999.905 7	−0.003 9	−0.003 4
7	999.901 1	999.896 4	999.891 6	999.886 6	999.881 5	999.876 2	999.870 8	999.865 2	999.859 5	999.853 7	−0.005 3	−0.003 5
8	999.847 7	999.841 6	999.835 3	999.828 9	999.822 3	999.815 7	999.808 8	999.801 9	999.794 7	999.787 5	−0.006 8	−0.003 5
9	999.780 1	999.772 6	999.764 9	999.757 1	999.749 2	999.741 1	999.732 9	999.724 6	999.716 1	999.707 5	−0.008 1	−0.003 4
10	999.678 7	999.689 8	999.680 8	999.671 7	999.662 4	999.653 0	999.643 4	999.633 7	999.623 9	999.014 0	−0.009 5	−0.003 3
11	999.603 9	999.593 7	999.583 4	999.572 9	999.562 3	999.551 6	999.540 8	999-529 8	999.518 7	999.507 4	−0.0108	−0.003 1
12	999.496 1	999.484 6	999.473 0	999.461 2	999.449 4	999.437 4	999.425 3	999.413 0	999.400 7	999.388 2	−0.012 1	−0.002 9
13	999.375 6	999.362 8	999.350 0	999.337 0	999.323 9	999.310 6	999.297 3	999.283 8	999.270 2	999.256 5	−0.0133	−0.002 6
14	999.242 7	999.228 7	999.2146	999.200 4	999.186 1	999.171 7	999.157 1	999.142 4	999.127 6	999.112 7	−0.0145	−0.002 3
15	999.097 7	999.082 6	999.067 3	999.051 9	996 036 4	999.020 8	999.005 1	998.989 2	998.973 3	998.957 2	−0.015 7	−0.002 0
16	998.941 0	998.924 7	998.908 3	998.891 7	998.875 1	998.858 3	998.841 4	998.824 4	998.807 3	998.790 1	−0.0168	−0.001 7
17	998.772 8	998.755 3	998.737 8	998.720 1	998.702 3	998.684 5	998.666 5	998.648 3	998.630 1	998.611 8	−0.0179	−0 001 4
18	998.593 4	998.574 8	998.556 2	998.537 4	998.510 5	998.499 5	998.480 4	998.461 2	998.441 9	998.422 5	−0.019 0	−0.001 1
19	998.403 0	998.383 3	998.363 6	998.343 8	998.323 3	998.303 7	998.283 6	998.263 3	998.242 9	998.222 4	−0.020 1	−0.000 9
20	998.2019	998.181 2	998.160 4	998.139 5	998.118 5	998.097 3	998.076 1	998.054 8	998.033 4	998.011 9	−0.021 2	−0.000 6
21	997.990 2	997.968 5	997.946 7	997.924 7	997.902 7	997.880 5	997.858 3	997.836 0	997.813 5	997.791 0	−0.022 2	−0.000 4
22	997.768 3	997.745 6	997.722 7	997.699 8	997.676 7	997.653 6	997.630 3	997.607 0	997.583 5	997.560 0	−0.023 2	−0.000 2
23	997.536 3	997.512 6	997.488 7	997.464 8	997.440 8	997.416 6	997.392 4	997.368 0	997.343 6	997.319 1	−0.024 2	−0.000 1
24	997.294 4	997.269 7	997.244 9	997.220 0	997.195 0	997.169 9	997.144 6	997.119 3	997.093 9	997.068 5	−0.025 2	0.000 0
25	997.042 9	997.017 2	996.991 4	996.965 5	996.939 6	996.913 5	996.887 3	996.861 1	996.834 7	996.808 3	−0.026 1	0.000 0
26	996.781 8	996.755 1	996.728 4	996.701 6	996.674 7	996.647 7	996.620 6	996.593 4	996.566 1	996.538 8	−0.027 0	0.000 0
27	996.511 3	996.483 7	996.456 1	996.428 4	996.400 5	996.3726	996.344 6	996.316 5	996.288 3	996.260 0	−0.028 0	0.000 0
28	996.231 6	996.203 2	996.174 6	996.146 0	996.1172	996.088 4	996.059 5	996.030 5	996.001 4	995.972 2	−0.028 9	0.000 0
29	995.943 0	995 913 6	995.884 2	995.854 6	995.825 0	995.795 3	995.765 5	995.735 6	995.705 6	995.675 6	−0.029 8	0.0000
30	995.645 4	995.615 2	995.584 8	995.554 4	995.523 9	995.493 4	995.462 7	995.431 9	995.401 1	995.370 1	−0.030 6	0.000 0
31	995.339 1	995.308 0	995.276 8	995.245 6	995.214 2	995.182 8	995.151 2	995.119 6	995.087 9	995.056 1	−0.031 5	0.000 0
32	995.024 3	991.992 3	991.960 3	994.928 2	994.896 0	994.863 7	994.831 3	994.798 3	994.766 3	994.733 7	−0.032 3	0.0000
33	994.701 0	994.668 2	994.635 3	994.602 1	991.569 3	994.536 2	994.503 0	994.469 7	994.436 4	994.402 9	−0.033 2	0.000 0
34	994.369 4	994.335 8	994.302 1	994.268 3	994.234 5	994.200 5	994.166 5	994.132 4	994.098 2	994.064 0	0.034 0	0 000 0
35	994.029 6	993.995 2	993.960 7	993.926 1	993.891 5	993.856 7	993.821 9	993.787 0	993.752 1	993.717 0	0.034 8	0.0000
36	993 681 9	993.646 7	993.611 4	993.576 0	993.540 6	993.505 0	993.469 4	993.433 8	993.398 0	993.362 2	0.035 6	0.000 0
37	993. 326 3	993.290 3	993.254 2	993.218 1	993.181 8	993.145 5	993.109 2	993.072 7	993.036 2	992.999 6	0.036 3	0.0000
38	992. 962 9	992.926 1	992.889 8	992.852 4	992.815 4	992.778 4	992.741 2	992.704 0	992.666 8	992.629 4	0.037 1	0.0000
39	992.592 0	992.554 5	992 516 9	992.479 2	992.4415	992.403 7	992.365 8	992.327 9	992.289 9	992.251 8	0.037 8	0.0000
40	992.213 6											

NOTE — Density of air-free distilled water at 15.5°C = 999.012 1 kg/m^3.

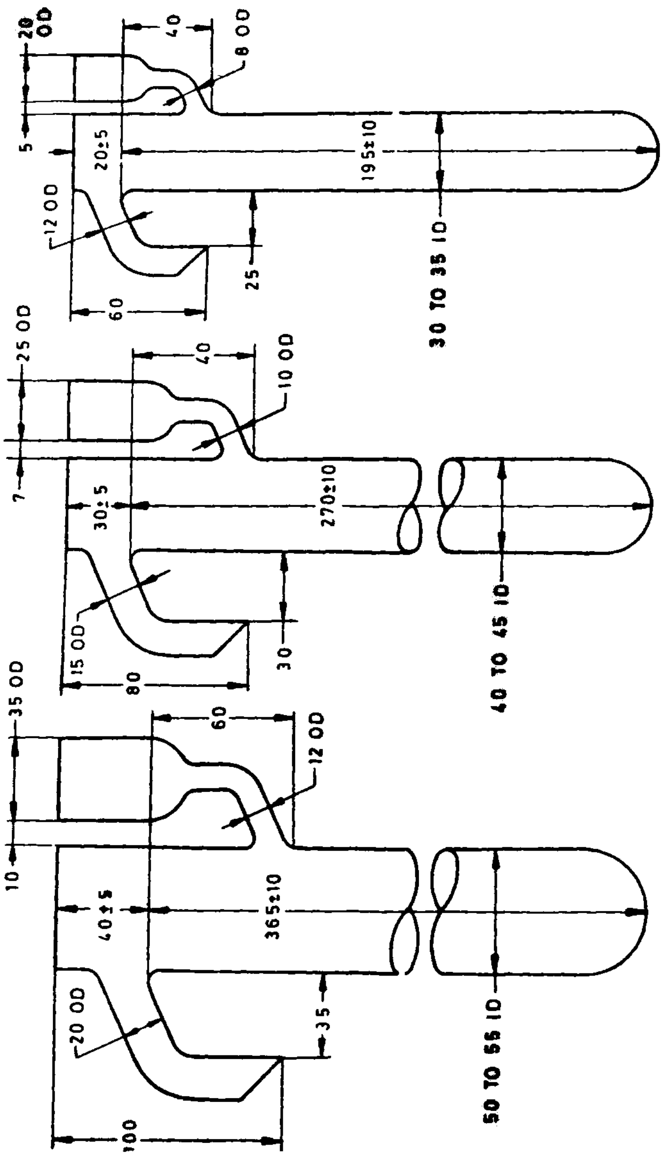

FIG 1 OVERFLOW VESSELS SUITABLE FOR OBSERVATION ON HYDROMETERS

TABLE 8 DIFFERENCE BETWEEN READINGS ON HYDROMETERS ADJUSTED FOR DENSITY AT 20°C OR 15°C

(*Clause* 7.1)

INDICATION OF HYDROMETER		READING ON DENSITY AT 15°C SCALE MINUS READING ON DENSITY AT 20°C SCALE
kg/m^3	g/ml	
(1)	(2)	(3)
600	0.6	0 1
700	0.7	0.1
800	0.8	0.1
900	0.9	0.1
1 000	1.0	0.1
1 100	1.1	0.1
1 200	1.2	—
1 300	1.3	—
1 400	1.4	—
1 500	1.5	—
1 600	1.6	—
1 700	1.7	—
1 800	1.8	—
1 900	1.9	—
2 000	2.0	—

7.2 The tabulated values arc the difference which should exist between the readings of similar instruments in the same surface tension category and having scales graduated in different units, and they apply when the hydrometers are subject to the same conditions in the same liquid. The differences are independent of the temperature of the liquid, and are based on a coefficient of cubical thermal expansion of glass of 25×10^{-6} ($°C^{-1}$).

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